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PNEUMATIC TIRE

## TECHNICAL FIELD

[0001] The present invention relates to pneumatic tires, and more particularly, to a pneumatic tire capable of improving uneven wear resistance and turning performance.

## TECHNICAL BACKGROUND

[0002] Conventionally, there are pneumatic tires having a tread surface in which a plurality of main grooves extend straight in the circumferential direction of the tire to thereby define circumferentially extending ribs (land portions), and pneumatic tires having a tread surface in which, in addition to the main grooves, lateral grooves which extend in the widthwise direction of the tire are disposed in predetermined intervals in the circumferential direction of the tire to define circumferentially extending block rows (land portions) by the main grooves and lateral grooves.

[0003] In such pneumatic tires, for example, as shown in FIG. 6, there is a pneumatic tire in which the ribs 13 formed between the main grooves 12 have ground contact surfaces 13x defined by a circular arc C1 in the tire meridian cross section, the circular arc C1 having a radius R1 of curvature which is the same as the radius R0 of curvature of a circular arc C0 defining the profile of the tread surface 11.

[0004] In pneumatic tires of this type, a ground contact pressure focuses on the outer end 13a of each rib 13 located

on the outer side M of a vehicle when the tire is mounted on the vehicle under service conditions which cause a great turning force, such as running of a circuit, and therefore, uneven wear such that the outer end wears locally is apt to occur. In particular, a high ground contact pressure is applied to the outer end 13a of a second land portion 13N when counted from the vehicle outer side M. Therefore, the outer end 13a thereof wears significantly, and there is a problem of deteriorating uneven wear resistance to a large extent.

[0005] Also, concentration of a ground contact pressure on each outer end 13a causes the inner end 13b of each of the land portions 13 to be susceptible to lifting and sliding. Especially, the inner end 13b of the second land portion 13N is greatly lifted and slid, resulting in creation of a problem of lowering a turning force.

#### DISCLOSURE OF THE INVENTION

[0006] An object of the present invention is to provide a pneumatic tire which can improve uneven wear resistance and turning performance under service conditions that cause a great turning force, such as running of a circuit.

[0007] In order to achieve the above object, a pneumatic tire according to present invention includes a tread surface having a plurality of main grooves extending straight in a circumferential direction of the tire, land portions extending in the tire circumferential direction being defined by the

plurality of main grooves, the land portions each having a ground contact surface comprising a first circular arc having a single curvature radius in tire meridian cross section,

[0008] wherein the ground contact surface of at least the land portion which is located second when counted from the outer side of a vehicle when the tire is mounted thereon, is arranged so as to have the first circular arc and at least a second circular arc connected thereto on the vehicle outer side thereof, wherein the circular arc located closer to the vehicle outer side has a smaller curvature radius and is positioned more inwardly away from the tread surface, and wherein the ratio  $d/D$  of the depth  $d$ , from the tread surface, of an intersection of the circular arc located closest to the vehicle outer side with a vehicle outer sidewall surface of the at least second land portion to the groove depth  $D$  of the main groove facing to the vehicle outer sidewall surface is 0.02 to 0.1.

[0009] As described above, the ground contact surface of the second land portion, when counted from the vehicle outer side, which significantly deteriorates uneven wear resistance and turning performance is arranged so as to have a conventional first circular arc and at least a second circular arc with a smaller curvature radius connected thereto on the vehicle outer side thereof, and the relationship between the depth  $d$  of an intersection of the second circular arc with the vehicle outer sidewall surface of the second land portion is specified as

mentioned above, whereby the outer end of the second land portion is effectively sunk radially inward of the tire from the tread surface.

[0010] Therefore, a more even distribution of the ground contact pressure on the second land portion can be obtained when a great turning force is applied thereto, for example, when running a circuit, whereby a high ground contact pressure applied onto the outer end can be avoided. Accordingly, uneven wear resistance can be improved, and turning performance can also be improved by suppressing the lowering of a turning force since the inner end side of the second land portion can be prevented from lifting and sliding.

[0011] Another pneumatic tire according to present invention includes a tread surface having a plurality of main grooves extending straight in a circumferential direction of the tire, land portions extending in the tire circumferential direction being defined by the plurality of main grooves, the land portions each having a ground contact surface comprising a first circular arc having a single curvature radius in tire meridian cross section,

[0012] wherein the ground contact surface of at least the land portion which is located second when counted from the outer side of a vehicle when the tire is mounted thereon, is arranged so as to have the first circular arc and a curved line connected thereto on the vehicle outer side thereof, wherein the curved

line is formed so as to extend more inwardly away from the tread surface toward the vehicle outer side, and wherein the ratio  $d/D$  of the depth  $d$ , from the tread surface, of an intersection of the curved line with a vehicle outer sidewall surface of the at least second land portion to the groove depth  $D$  of the main groove facing to the vehicle outer sidewall surface is 0.02 to 0.1.

[0013] Such arrangement can also improve uneven wear resistance and turning performance under service conditions which cause a great turning force, such as running of a circuit, in the same way as described above.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a partial front view of a tread surface showing an embodiment of a pneumatic tire according to the present invention.

[0015] FIG. 2 is a tire meridian partial enlarged cross-sectional view of the tire of FIG. 1.

[0016] FIG. 3 is a tire meridian partial enlarged cross-sectional view showing an alternative embodiment of a pneumatic tire according to the present invention.

[0017] FIG. 4 is a tire meridian partial enlarged cross-sectional view showing another alternative embodiment of a pneumatic tire according to the present invention.

[0018] FIG. 5 is a tire meridian partial enlarged cross-sectional view showing still another alternative

embodiment of a pneumatic tire according the present invention.

[0019] FIG. 6 is a tire meridian partial enlarged cross-sectional view showing a conventional pneumatic tire.

[0020] FIG. 7 is a tire meridian partial enlarged cross-sectional view showing the comparative tire 1 used in Example.

[0021] FIG. 8 is a tire meridian partial enlarged cross-sectional view showing the comparative tire 2 used in Example.

[0022] FIG. 9 is a tire meridian partial enlarged cross-sectional view showing the comparative tire 3 used in Example.

#### BEST MODES FOR CARRYING OUT THE INVENTION

[0023] The embodiments of the present invention will be described in detail below with reference to the drawings.

[0024] Referring to FIG. 1, there is shown an embodiment of a pneumatic tire according to the present invention, in which a tread surface 1 has a plurality of (three in the drawing) main grooves 2 which extend straight along a circumferential direction T of the tire, and ribs (land portions) 3 extending in the tire circumferential direction T are defined by the main grooves 2. Reference character CL denotes a tire center line.

[0025] The land portion 3A which located second when counted from the outer side of a vehicle when the tire is mounted thereon, has a ground contact surface 3x which consists of a first circular

arc C1 having a curvature radius R1, and a second circular arc C2 having a curvature radius R2, as shown in a cross-sectional drawing of FIG. 2 taken along the meridian of the tire, the second circular arc C2 being connected to the first circular arc C1 on the tire outer side thereof.

[0026] The first circular arc C1 is identical to a circular arc C0 with a curvature radius R0 defining the profile of the tread surface 1, and the first circular arc C1 and the second circular arc C2 are connected to each other on the same tangent line. The ground contact surface 3x of each of other land portions 3 consists of the first circular arc C1 having a curvature radius R1.

[0027] The curvature radius R2 of the second circular arc C2 located on the vehicle outer side (the outer end 3A1 of the land portion 3A) is smaller than the curvature radius R1 of the first circular arc C1, and the second circular arc C2 is formed such that it extends progressively inwardly away from the circular arc C0 defining the profile of the tread surface 1 to the vehicle outer side end of the second circular arc.

[0028] The ratio d/D of the depth d, from the circular arc C0, of the intersection P of the second circular arc C2 with the vehicle outer sidewall surface 3y of the second land portion 3A facing to the main groove 2 on the outer side thereof to the groove depth D of the outer side main groove 2 ranges from 0.02 to 0.1. The depth d of the intersection P is the length measured

in a direction orthogonal to the tire axis from a tangent line S to the intersection P, the tangent line S being a tangent line drawn in FIG. 2 between the ground contact surfaces 3x of the land portions 3 located on the both sides of the main groove 2 which is on the outer side of the second land portion 3A. The depth D of the main groove 2 is the length measured in a direction orthogonal to the tire axis from the groove bottom 2x to the tangent line S in the center of the groove width.

[0029] According to the present invention, the ground contact surface 3x of the land portion 3A which provides a great affection to the deterioration of uneven wear resistance and turning performance has the second circular arc C2 with a smaller curvature radius which is connected to the conventional first circular arc C1 on the vehicle outer side thereof, and the depth d of the intersection P of the second circular arc C2 with the vehicle outer sidewall surface 3y of the land portion 3A is specified as described above, whereby the outer end 3A1 is effectively sunk tire-radially inward from the position of the conventional tread surface to thereby allow for a more even distribution of ground contact pressure of the tread surface when a great turning force is applied thereto. Therefore, concentration of ground contact pressure on the outer end 3A1 can be avoided.

[0030] Accordingly, uneven wear resistance can be improved, and turning performance can also be improved since the inner

end 3A2 side of the land portion 3A can be prevented from lifting and sliding.

[0031] If the ratio  $d/D$  is less than 0.02, it is difficult to effectively improve turning performance and uneven wear resistance. If the ratio  $d/D$  is more than 0.1, turning performance can not effectively be improved.

[0032] Referring to FIG. 3, there is shown an alternative embodiment of a pneumatic tire according to the present invention. The ground contact surface 3x of the second land portion 3A consists of a first circular arc C1 with a curvature radius R1, a second circular arc C2 with a curvature radius R2 and a third circular arc C3 with a curvature radius R3, the curvature radii R1, R2 and R3 being different from one another. The curvature radius R1 of the first circular arc C1 is the greatest of the curvature radii R1, R2 and R3, and the curvature radius R3 of the third circular arc C3 located on the vehicle outer side is the smallest thereof.

[0033] The ground contact surface 3x consists of the three circular arcs C1, C2 and C3, as described above, and the ratio  $d/D$  of the depth  $d$  of the intersection P of the third circular arc C3 on the vehicle outer side with the vehicle outer sidewall surface 3y of the second land portion 3A facing to the main groove 2 on the outer side thereof to the groove depth D of the main groove 2 facing to the vehicle outer sidewall surface 3y is set in the same way as described above, thereby allowing the same

effects as mentioned above to be obtained.

[0034] In the present invention, referring to the relationship between the depth  $d$  of the above intersection  $P$  and the groove width  $W$  of the main groove 2, the ratio  $d/W$  may range from 0.01 to 0.15. If the ratio  $d/W$  is less than 0.01, it is difficult to effectively improve turning performance and uneven wear resistance, and if the ratio  $d/W$  is more than 0.15, turning performance can not effectively be improved.

[0035] In the case of the ground contact surface 3x consisting of the first and second circular arcs  $C1$  and  $C2$  as shown in the embodiment of FIG. 2, the ratio  $R1/R2$  of the curvature radius  $R1$  of the first circular arc  $C1$  to the curvature radius  $R2$  of the second circular arc  $C2$  may be 2 to 10. If the ratio  $R1/R2$  is less than 2, the effect of improving turning performance is small. If the ratio  $R1/R2$  is more than 10, the effects of improvement in turning performance and uneven wear resistance are small.

[0036] In the case of the ground contact surface 3x consisting of the first, second and third circular arcs  $C1$ ,  $C2$  and  $C3$ , as shown in the embodiment of FIG. 3, referring to the relationships between the curvature radii  $R1$ ,  $R2$  and  $R3$  of the circular arcs  $C1$ ,  $C2$  and  $C3$ , it is preferable that the ratio  $R1/R2$  and the ratio  $R2/R3$  be 2 to 10, respectively. If each ratio is less than 2, the effect of improving turning performance is small. If each ratio is more than 10, the effects of improvement in turning

performance and uneven wear resistance are small.

[0037] In the present invention, the ground contact surface mentioned above may consist of a plurality of circular arcs which are three or more, and may comprise the first circular arc C1 and at least the second circular arc C2 connected thereto on the vehicle outer side thereof, in which the circular arc located closer to the vehicle outer side has a smaller curvature radius. In this case, the depth d of the intersection P is the depth of an intersection of the circular arc located nearest to the vehicle outer side with the vehicle outer sidewall surface 3y.

[0038] As shown in FIG. 4, the ground contact surface 3x may also consist of the first circular arc C1 and a curved line 4 connected thereto on the same tangent line on the vehicle outer side thereof, the curved line 4 having such curvature radii that they are smaller in a continuous fashion toward the vehicle outer sidewall surface 3y, and being formed such that the curved line extends progressively inwardly away from the circular arc C0 defining the profile of the tread surface 1 to the vehicle outer side end of the curved line. In the case of employing such curved line 4 also, the ratio d/D of the depth d, from the circular arc C0, of the intersection P of the curved line 4 with the vehicle outer sidewall surface 3y to the groove depth D of the main groove 2 facing to the vehicle outer sidewall surface 3y is set to the same range as described above, thereby allowing the same effects to be obtained.

[0039] As shown in FIG. 5, the ground contact surface 3x may also include an inner circular arc C2' which is smaller in curvature radius than the first circular arc C1 and is connected to the first circular arc C1 on the same tangent line on the vehicle inner side thereof, the inner circular arc being formed such that the section of the ground contact surface 3x positioned at the inner end 3A2 of the land portion 3a extends progressively inwardly away from the circular arc C0 defining the profile of the tread surface 1 toward the vehicle inner side.

[0040] Consequently, when turning to such an opposite direction that the inner end 3 of the land portion 3a is located on the outer side relative to the turning, a ground contact pressure focusing on the inner end 3A2 can be avoided. Therefore, uneven wear resistance of the inner end 3A2 can be improved, and turning performance in turning to the opposite direction can be enhanced.

[0041] With Reference to the relationship between the curvature radius R2' of the circular arc C2' and the curvature radius R1 of the first circular arc C1, the ratio R1/R2' may be 2 to 10. If the ratio R1/R2' is less than 2, the effect of improving turning performance in turning to the opposite direction is small, and if the ratio R1/R2' is more than 10, the effects of improvement in turning performance in turning to the opposite direction and uneven wear resistance of the inner end 3A2 are small.

[0042] The ratio  $d'/D$  of the depth  $d'$  of the intersection  $P'$  of the circular arc  $C2'$  with the vehicle inner sidewall surface  $3z$  of the second land portion  $3A$  facing to the main groove  $2$  on the inner side thereof to the groove depth  $D$  of the inner side main groove  $2$  may range from  $0.01$  to  $0.1$ . If the ratio  $d'/D$  is less than  $0.01$ , it is difficult to effectively improve turning performance in turning to the opposite direction and uneven wear resistance of the inner end  $3A2$ . If the ratio  $d'/D$  is more than  $0.1$ , turning performance in turning to the opposite direction can not effectively be improved.

[0043] In the embodiments mentioned above, only the ground contact surface  $3x$  of the second land portion  $3A$  when counted from the vehicle outer side  $M$  is formed as described above. However, the ground contact surface  $3x$  of the third or fourth land portion  $3$  may have the same arrangement, and at least the ground contact surface  $3x$  of the second land portion  $3A$  which greatly affects the lowering of uneven wear resistance and turning performance may be formed as described above.

[0044] The main grooves  $2$  referred in the present invention have groove widths equal to or greater than  $2\%$  of the tire nominal width, and circumferentially extending grooves having groove widths narrower than those do not correspond to the main grooves of the present invention referred herein.

[0045] In the above embodiments, examples are shown of the case where there are provided ribs as land portions. However,

the present invention may include tires which have tread patterns of FIG. 1 further including lateral grooves extending in the tire widthwise direction in predetermined intervals along the tire circumferential direction and are provided with land portions comprising block rows extending in the tire circumferential direction T instead of the ribs.

#### Example 1

[0046] Tires 1, 2 and 3 according to the present invention were prepared, respectively, having an equal tire size of 235/45ZR17, the present invention tires 1 each having a tread pattern shown in FIG. 1 in which the ground contact surface of the second land portion, when counted from the outer side of a vehicle when the tire was mounted thereon, consisted of two circular arcs C1 and C2 with curvature radii R1 and R2 as shown in FIG. 2, the present invention tires 2 each having a tread pattern shown in FIG. 1 in which the ground contact surface of the second land portion consisted of three circular arcs C1, C2 and C3 with curvature radii R1, F2 and R3 as shown in FIG. 3, the present invention tires 3 each having a tread pattern shown in FIG. 1 in which the ground contact surface of the second land portion consisted of four circular arcs C1, C2, C3 and C2' with curvature radii R1, F2, R3 and R2' as shown in FIG. 4.

[0047] Conventional tires each having an arrangement shown in FIG. 6, and comparative tires 1 to 4 were also prepared, respectively, the comparative tires 1 and 2, as shown in FIGS.

7 and 8, having second land portions the ground contact surfaces of which consisted of a circular arc C1 having a curvature radius R1 smaller than the curvature radius R0 of the circular arc C0 defining the profile of the tread surface, the comparative tires 3, as shown in FIG. 9, having the same arrangement as the conventional tire of FIG. 6 except that the outer end of the second land portion was chamfered with an circular arc having a radius Rx, the comparative tires 4 having the same arrangement as the present invention tire 2 except that the curvature radius R1 was larger than the curvature radius R2 and the curvature radius R2 was smaller than the curvature radius R3.

[0048] Tires 4 to 6 according to the present invention and comparative tires 5 and 6 were further prepared, respectively, each having an arrangement shown in FIG. 3 and the ratio d/D of the depth d of the intersection to the groove depth D of the main groove varied as shown in Table 1. The curvature radii R0, R1, R2, R3 and R2' of the circular arcs and the ratios d/W were as shown in Table 1.

[0049] Each test tire was mounted on a 17×8JJ sized rim, and an air pressure of 220 kPa was applied thereto. The evaluation tests for turning performance and uneven wear resistance were performed in the following measurement methods, obtaining the results shown in Table 1.

#### Turning Performance

[0050] Each test tire was attached to an indoor drum test machine

and a cornering force applied thereto was measured under conditions of a load of 4.0 kN, a running speed of 100 km/h, a slip angle of 4 degrees, and a camber angle of 3 degrees. The evaluation results of the test tires were represented by the index on the basis of the conventional tire as 100. The greater the index value, the better the turning performance. The index value equal to or more than 105 is of a remarkable effect.

#### Uneven Wear Resistance

[0051] Each test tire was attached to a four-wheel driven car of 2 litter displacement, and the amount of wear of the second land portion thereof was measured after running a circuit course of 2.1 km ten times. The results of the test tires were evaluated by a 10-point method. The greater the value, the better the uneven wear resistance. The value equal to or more than 7 is practically effective in improvement.

Table 1

	Conventional 1 Tire	Comparative Tire 1	Comparative Tire 2	Comparative Tire 3	Comparative Tire 4
R0 (mm)	1000	1000	1000	1000	1000
R1 (mm)	1000	335	600	1000	1000
R2 (mm)	--	--	--	--	100
R3 (mm)	--	--	--	--	300
R2' (mm)	--	--	--	--	--
R <sub>x</sub> (mm)	--	--	--	4.25	--
d/D	--	--	--	0.5	0.035
d/W	--	--	--	0.304	0.021
Turning Performance	100	104	103	102	105
Uneven Wear Resistance	2	6	6	6	6
	Present Invention Tire 1	Present Invention Tire 2	Present Invention Tire 3	Comparative Tire 5	Present Invention Tire 4
R0 (mm)	1000	1000	1000	1000	1000
R1 (mm)	1000	1000	1000	1000	1000
R2 (mm)	250	300	300	300	300
R3 (mm)	--	100	100	70	75
R2' (mm)	--	--	150	--	--
R <sub>x</sub> (mm)	--	--	--	--	--
d/D	0.035	0.035	0.035	0.017	0.02
d/W	0.021	0.021	0.021	0.021	0.021
Turning Performance	106	108	108	103	105
Uneven Wear Resistance	7	8	8	5	7
	Present Invention Tire 5	Present Invention Tire 6	Comparative Tire 6		
R0 (mm)	1000	1000	1000		
R1 (mm)	1000	1000	1000		
R2 (mm)	300	300	300		
R3 (mm)	100	100	100		
R2' (mm)	--	--	--		
R <sub>x</sub> (mm)	--	--	--		
d/D	0.06	0.1	0.12		
d/W	0.021	0.021	0.021		
Turning Performance	107	105	103		
Uneven Wear Resistance	8	8	7		

[0052] As can be seen from Table 1, the present invention tires can effectively improve turning performance and uneven wear resistance.

Example 2

[0053] Test tires 1~5 were prepared, respectively, each having the same tire size as in Example 1 and the ratio  $d/W$  of the depth  $d$  of the intersection to the groove width  $W$  of the main groove 2 shown in Table 2 in the above present invention tire 2. The curvature radii  $R_0$ ,  $R_1$ ,  $R_2$  and  $R_3$  of the circular arcs and the ratios  $d/D$  were as shown in Table 2.

[0054] Evaluation tests for turning performance and uneven wear resistance were conducted on each of the test tires as in Example 1. The results shown in Table 2 were obtained.

Table 2

	Test Tire 1	Test Tire 2	Test Tire 3	Test Tire 4	Test Tire 5
$R_0$ (mm)	1000	1000	1000	1000	1000
$R_1$ (mm)	1000	1000	1000	1000	1000
$R_2$ (mm)	300	300	300	300	300
$R_3$ (mm)	100	100	100	100	100
$d/D$	0.035	0.035	0.035	0.035	0.035
$d/W$	0.008	0.01	0.10	0.15	0.16
Turning Performance	103	106	105	105	103
Uneven Wear Resistance	3	7	8	8	7

[0055] As seen in Table 2, it is understood that the ratio  $d/W$  of the depth  $d$  of the intersection to the groove width  $W$  of the main groove 2 preferably ranges from 0.01 to 0.15.

[0056] As illustrated above, according to the present invention, the ground contact surface of at least a land portion which is located second when counted from the vehicle outer side when the tire is mounted thereon, is arranged so as to have a conventional first circular arc and at least a second circular arc which is connected thereto on the vehicle outer side thereof

and has a curvature radius smaller than that of the first circular arc, or so as to have a conventional first circular arc and a curved line which is connected thereto on the vehicle outer side thereof and is formed such that the curved line extends progressively inwardly away from the tread surface to the vehicle outer side end of the curved line, and the ratio  $d/D$  of the depth  $d$  of the intersection  $P$  of the second circular arc or curved line with the vehicle outer sidewall surface of the second land portion is specified in the above range, whereby turning performance and uneven wear resistance can effectively be improved under service conditions which cause a great turning force, such as running of a circuit.

#### INDUSTRIAL APPLICABILITY

[0057] The present invention having the aforementioned excellent effects is very effectively applicable to pneumatic tires to be mounted on a vehicle which runs, for example, a circuit.